

Strontium Distribution For The Carbontes of The
Flagstaff Formation

Ephraim, Utah

By

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Abstract:

The strontium concentrations of twenty nine samples of carbonate rocks from the Flagstaff formation at Fairview Canyon in Ephraim, Utah were determined by X-ray fluorescence. X-ray diffraction was used to determine the dolomite content in the samples. An inverse relationship was expected to hold between the dolomite content and the strontium concentration. As a result of this investigation it has been found that the strontium concentration varies directly with the dolomite content . In as much as the dolomite content is controlled by dolomitization, one concludes that dolomitization may affect the strontium concentration in either one of three ways: (1) it may increase the strontium concentration, (2) it may decrease the strontium content or (3) in case of primary strontium, dolomitization may have no effect on the Sr concentration. The presence of pelecypods, ostracods and gastropods may have a positive effect on the strontium content. Until the strontium distribution among these fossils is determined

no further comment on their exact role in determining the strontium concentration can be made here. In so far as the Flagstaff dolomites show higher strontium concentration than the limestones, one sees that crystall form of the Flagstaff carbonates is not of primary importance in controlling the strontium content.

Introduction:

The purpose of this investigation was to determine the Sr concentrations in samples of carbonate rocks from the Flagstaff formation in Ephraim, Utah. The Sr concentrations were related to the amount of dolomite in order to find out what happens to Sr as calcite is replaced by dolomite. In view of the work that has been done by previous investigators, an inverse relationship was expected to hold between the strontium concentrations and the amount of dolomite .

For example, Campbell et al.(1965) found that the strontium concentrations of marine carbonates decreased when the dolomite content increased . Müller(1967) pointed out that the Sr concentration varies directly with the aragonite content. It was shown that considerable amounts of Sr were lost as aragonite changed to calcite (Turekian and Kulp 1956; Campbell et al.1965) . The effective ionic radii of Ca, Mg, and Sr are 0.99\AA , 0.66\AA , and 1.12\AA respectively. Thus it appears that most of the strontium introduced

into the carbonate rocks is substituted for Ca .

The Ca content is not the only factor that determines the Sr concentration. Chilinger et al.(1967b) suggested that Sr does not have to be in the carbonate lattices. Graf (1960) pointed out that celestite, SrSO_4 , may be present as an accessory mineral in carbonate sediments. If so then the introduction of Sr into the carbonate rocks is partially affected by the apparent difference in size among the Ca, Mg, and Sr ions . Yet our expectations were for the strontium concentrations to increase with increasing calcite content and to decrease with increasing dolomite content.

Of the twenty nine samples used in this investigation twenty five were collected from a measured stratigraphic section at Fairview Canyon, along Utah highway 3 . Samples T-1, T-2, T-3 and L-1 are collected at random from the Flagstaff formation in the vicinity of the Nine Mile Canyon in Ephraim.

The dolomite/calcite ratios were determined by X-ray diffraction using a calibration curve obtained by analysis of weighed mixtures of calcite and dolomite . The calibration curve was prepared by Dr. M.P.Weiss.

The strontium concentrations were determined by X-ray fluorescence using the Sr K-~~α~~X-radiation. Five standard samples whose strontium concentrations had been determined by isotope dilution

were used for calibration. The standards were prepared by Dr. G. Faure . By relating the strontium intensities of the standard samples to the intensities of the Sr peaks of the samples, the Sr concentrations were determined.

Geology of the Flagstaff Formation :

The Flagstaff formation derived its name from the Flagstaff peak of the Wasatch plateau. The rocks are Tertiary in age (upper Paleocene - lower Eocene) . The rocks vary in thickness from 300 to 800 feet (Spieker 1949:32) . The Flagstaff formation consists chiefly of fresh water limestone which is dense and fine in grain size . The color of the rocks varies but in general it is cream to tan .

The general lithologic features of the limestone suggest that chemical processes and/or biological activities were involved in its formation. In the Wasatch plateau area the Flagstaff formation contains an altered dense material that resembles a volcanic ash (Spieker et al. 1925) .

The limestone contains assemblages of fresh water fossils. The Eocene Flagstaff contains gastropod genera Goniobasis, Gyraulus and Physa (LaRocque 1956) . The Paleocene Flagstaff is distinguished by the presence of gastropod genera Viviparus, Lioplacodes and Hydrobia (LaRocque 1956) . The rocks contain some Ostracods

(Spieker et al. 1925). Pelecypods have also been identified (Roy, 1962).

In the Wasatch plateau area of central Utah, the Flagstaff formation is considered to be a member of the Wasatch formation (Spieker et al. 1925). In the northern Wasatch plateau, the Flagstaff limestone is overlain at places by the Colton formation which in turn is overlain by the Green River formation. The North Horn formation underlies the Flagstaff and is underlain by the Price River formation. Figure 1 shows the succession of the above mentioned formations.

Collecting and Preparing of the Samples :

The samples of the Flagstaff formation were collected from a measured stratigraphic section located at Fairview Canyon along Utah highway 3, 2.6 miles east of the railway road intersection in Ephraim, Utah. Samples T-1, T-2, T-3 and L-1 were collected at random from the Flagstaff formation in the vicinity of the Nine Mile Canyon in Ephraim. The section contains ledges of splintery limestone and sandstone. Shaly mudstone, cherty limestone as well as limy mudstone are also recognized. Toward its top, the section becomes more dolomitic in its composition; it becomes less dolomitic toward its bottom. The dolomite content^{does} not seem to vary systematically throughout the section (see discussion of

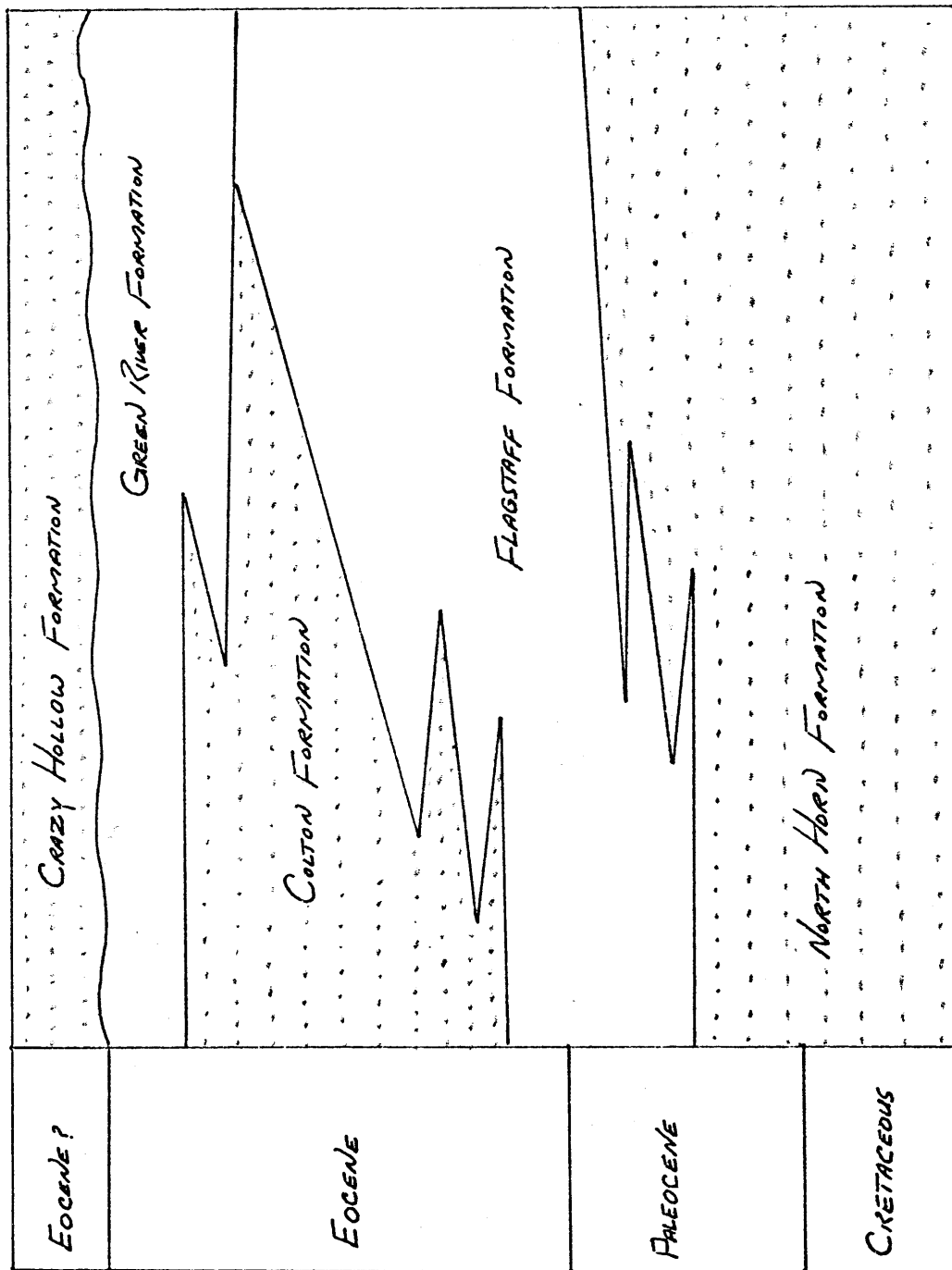


FIGURE 1, TERTIARY FORMATIONS IN CENTRAL UTAH;

MODIFIED AFTER LAROCQUE, 1956

dolomite/calcite ratios). Figure 2 shows the general lithology of the section..

The samples were crushed and ground in a steel mortar to pass a 300-mesh screen. The powder was mounted on clean glass slides in a mixture of rubber cement and acetone for X-ray diffraction analysis.

Determining the Dolomite/Calcite Ratios :

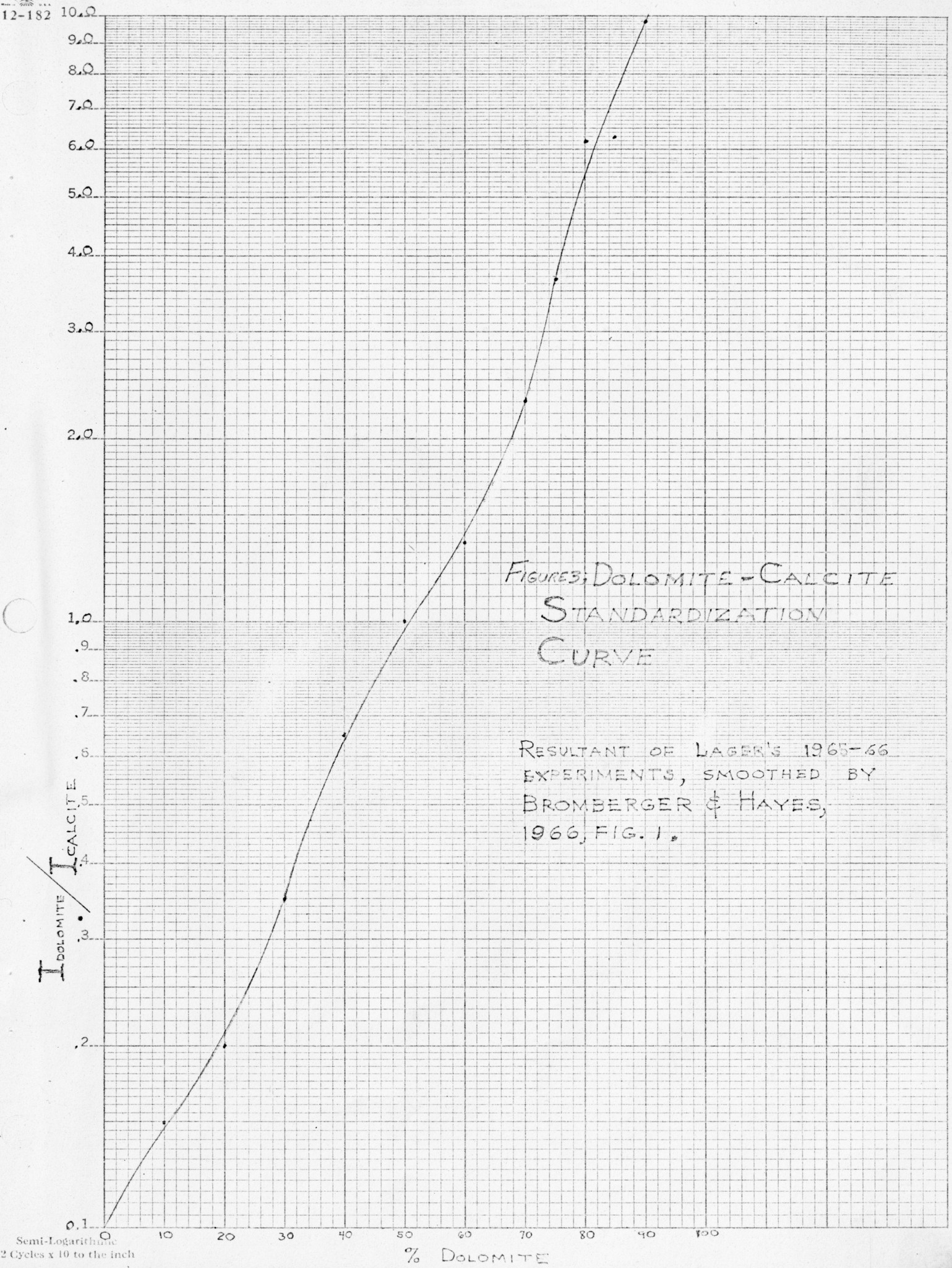
In order to yield satisfactory diffraction results, two readings were obtained for every calcite and dolomite maximum ($2\theta = 29.3^\circ$ and 31° respectively) and the average was used in the final calculations. The dolomite concentration was determined for the twenty nine samples by making use of a calcite calibration curve, figure 3 , as follows :

(1) the calcite peak height was divided into the corresponding dolomite peak height (2) the graph was entered at left and the percent dolomite was read along baseline (3) percent calcite is equal to $100 - \% \text{ dolomite}$.

The dolomite content of the samples was found to vary from 100% to 0%. No systematic variation is seen throughout the section in the % dolomite and the % calcite (figure 4) . From bottom of the section upward , the dolomite content seems to decrease continuously until it reaches a minimum of 0% in the interval between 16 and 52 feet. It then increases to attain a maximum of

FORMATION	SAMPLE	THICKNESS	COLUMNAR SECTION	CHARACTER
FLAGSTAFF	3*	43'		Limestone with limonitic streaks. Shaly, limy mudstone.
	4*			
	5-1, 5*			
	6*	40'		Pale orange limestone in thick ledges. Shaly mudstone, gray in color
	7*			
	8*			
	9*	39'		Limestone, greenish gray to dark. Limestone, splintery.
	10*			
	11*			
	12*			
	13*	52'		Sandy siltstone; shale and mudstone. Fine grained, yellowish gray limestone
	14*			
	15*			
	16*			
	17*			
	18*	46'		Marly limestone. A lens of coarse grained sandstone
	19*			
	20*			
	21*	60'		Limy shale, greenish gray; mudstone. Fine grained brownish gray to dark gray limestone.
	22, 23*			
	24*			
	25*			

FIGURE 2. COLUMNAR SECTION, FLAGSTAFF FORMATION, FAIRVIEW CANYON, EPHRAIM, UTAH. [With additional information from Weiss. M.P. 1967]



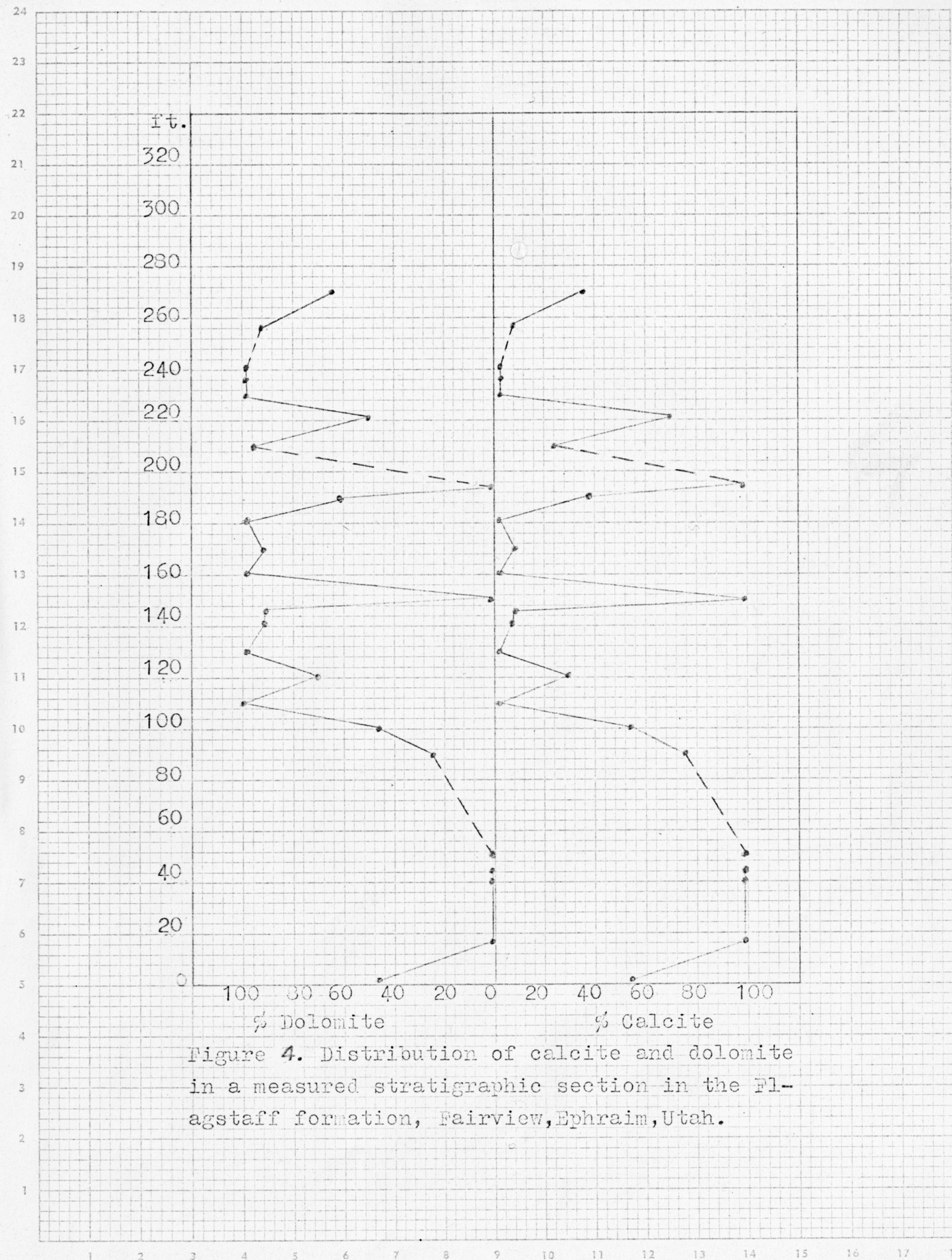


Figure 4. Distribution of calcite and dolomite in a measured stratigraphic section in the Flagstaff formation, Fairview, Ephraim, Utah.

Of 100% over an interval of 58ft. A remarkable increase in the %calcite characterizes the interval between the 145 ft and 160 ft mark. Beyond this point, except for sample nine (195') , the % dolomite remains higher untill top of the section is reached (table 1) .

Moreover, it appears that dolomitization has affected some beds in the section, but not others. This was not unexpected for dolomitization is not only controled by the chemical composition of the carbonate rocks in relation to the surrounding beds but also by the structural and environmental changes that take place during and after the deposition of the rocks. In as much as the distribution of at least one minor element (strontium) varies considerably , the environmental conditions that brought about the apparent selectivity must have varied proportionally.

Graf (1960) pointed out that according to Strakov the rate of evaporation as is controled by water temprature affects to a large extent the formation of dolomite .If so then one concludes that any relative increase in the water temprature up to a point yet to be determined, implies a relative increase in the rate of dolomitization, other variables being constant.

Dolomites have been observed to form along or near joints and fractures (Graf 1960) . In so far as the formation

Table 1, dolomite/calcite ratios; %dolomite and %calcite .

Sample	Position feet	Calcite Average cm	Dolomite Average cm	D/C	%dolomite	%calcite
25	4	8.35	7.45	0.89	48	52
24	16	17.85	0	0	0	≈100
23	40	20.25	0	0	0	≈100
22	42	18.00	1.65	0.09	-	≈100
21	52	17.30	.45	0.02	-	≈100
20	90	0.55	13.65	27.30	>90	<10
19	100	24.15	20.3	0.84	46	54
18	110	0	13.2	∞	100	-
17	120	8.0	19.85	2.48	71	29
16	130	0	8.30	∞	≈100	-
15	140	0.2	10.95	54.9	>90	<10
14-2	145	0.55	6.85	12.40	>90	<10
14	150	1 2.55	0.55	0.04	-	≈100
13	160	0	9.55	∞	≈100	-
12	170	1.07	11.0	10.25	>90	<10
11	180	0	14.3	∞	≈100	-
10	190	16.5	24.0	1.5	62	38
9	195	24.0	0	0	0	≈100
8	210	2.9	10.4	3.58	76	24
7	220	17.55	17.9	1.01	51	49
6	230	0	21.15	∞	≈100	-
5-1	236	0	22.75	∞	≈100	-
5	240	00	21.65	∞	≈100	-
4	255	1.4	14.35	10.25	>90	<10

Table 1 , continued .

Sample	Position feet	Calcite Average cm	Dolomite Average cm	D/C	%dolomite	%calcite
3	270	4.75	8.75	1.84	64	36
T-1	-	0	17.55	∞	≈ 100	-
T-2	-	1.85	15.15	8.20	87	13
T-3	-	4.85	9.45	1.95	67	33
L-1	-	0	19.50	∞	≈ 100	-

of dolomite is affected by the movements of replacing solutions, permeability must also affect dolomitization .

Strontium Distribution :

The strontium concentrations were determined by making use of the X- radiation generated by ionizing inner shells of the strontium atoms. A topaz crystal was used while the primary X-rays were generated from a Pt-target tube operated at 45 ma and 65 kvp . Two readings were obtained for each sample and the average was used in the final calculations. The K- α X-radiation was recorded at 37.72° (2θ) . The X-ray chart used had a range of 10 units and the X-ray intensity over this range was determined. Thus the intensities of the Sr peaks were obtained by relating the known intensity to the height of the measured Sr peaks .

The strontium concentrations for the five standards that were measured by Dr. G. Faure are shown on table 2 . Consequently, the strontium concentrations for the twenty nine samples were determined in the following manner:

(1) intensities of the K- α X-ray of Sr for the standards were divided into the corresponding concentrations, (2) an average value " h " was obtained , and (3) strontium concentration is equal to the intensity of unknown sample/h . Table 2 records the determined Sr concentrations .

In figure 5 the Sr concentrations of the standards are plotted against the corresponding intensities . Where the intensity of a given sample is measured, its strontium concentration can readily be determined using the calibration curve shown in figure 5 .

It has been pointed out earlier that Campbell et al . (1964) found that the Sr concentration tends to decrease as the dolomite content increases. Accordingly a noticable reduction in Sr might be expected as a result of dolomitization . Müller(1967) noted that carbonate mineralogy of recent Indian ocean sediments off the eastern^{Coast} of Somalia affects the Sr concentration . Pilkey and Hower (1960) conclude that the Mg content is directly related to both water temprature and salinity and that the Sr concentraion

Table 2, strontium concentrations .

Sample	Position feet	Sr (average) inches	Scale	Intensity cps	Sr Concentration ppm
25	4	2.26	500	113	246
24	16	2.36	500	118	251
23	40	1.18	500	59	128
22	42	2.05	500	102.5	222
21	52	2.31	500	115	250
20	90	2.24	500	112	244
19	100	3.43	500	171.5	372
18	110	2.90	500	145	315
17	120	2.86	500	145	311
16	130	2.43	500	121.5	263
Standard No.146		1.79	200	35.8	65.1
15	140	2.23	500	111.5	243
14-2	145	2.92	500	146	318
14	150	2.36	500	118	257
13	160	5.66	500	283	615
12	170	1.17	1000	117	255
11	180	2.30	1000	230	500
10	190	2.81	1000	281	612
Standard No.308		1.83	200	36.6	166.7
9	195	1.84	1000	184	400
8	210	2.23	1000	223	485
Standard No.133		4.21	1000	421	1506
7	220	2.68	1000	268	583
6	230	3.70	1000	370	805

Table 2 , continued .

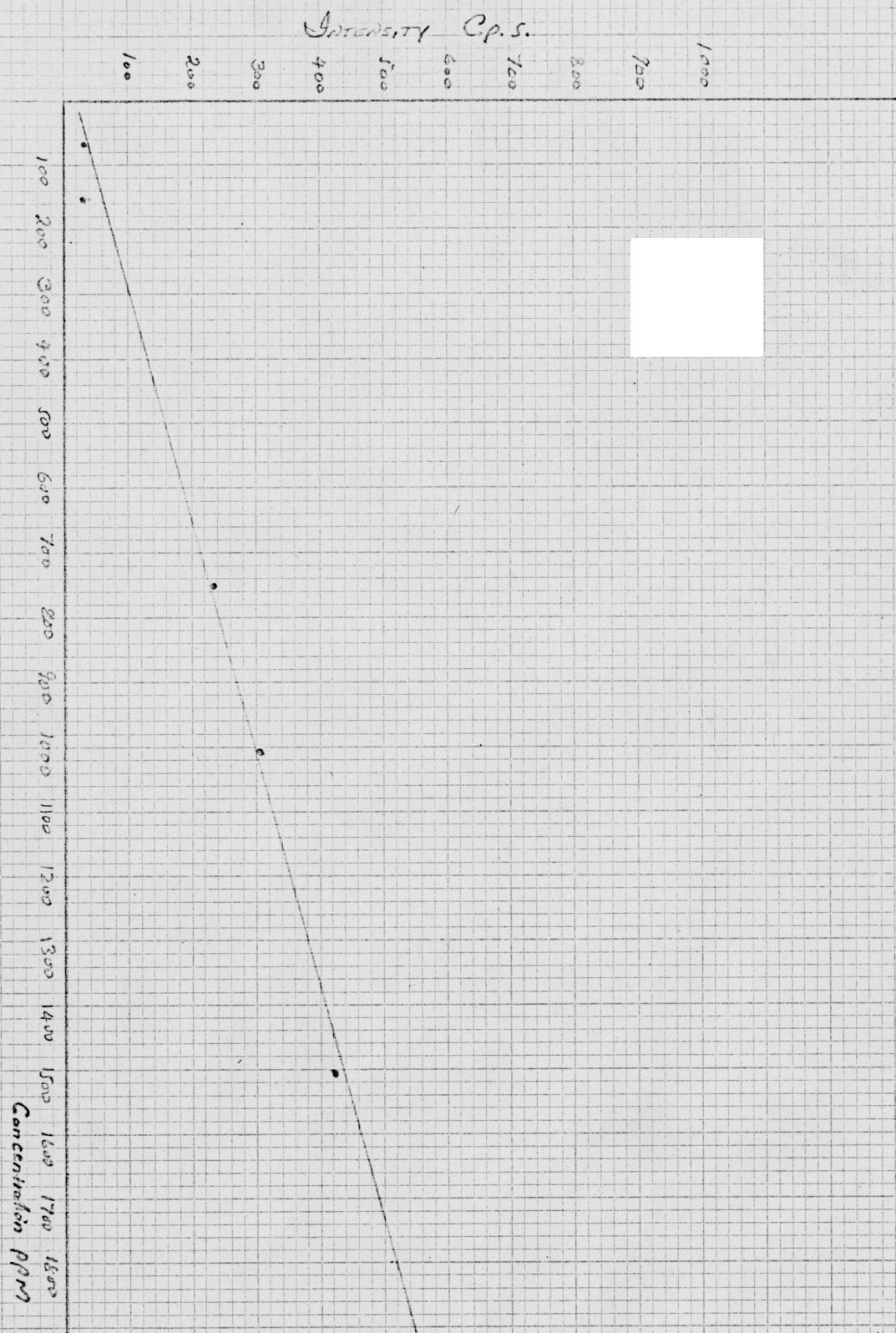
Sample	Position feet	Sr (average) inches	Scale	Intensity cps	Sr Concentration ppm
5-1	236	7.0	1000	700	1520
5	240	8.4	1000	840	1825
4	255	3.12	500	156	339
Standard No.309		2.4	500	239	752.3
3	270	6.0	500	302	657
T-1	-	7.6	500	380.5	828
T-2	-	7.45	500	372.5	812
T-3	-	6.86	500	343	745
L-1	-	1.79	500	89.5	194.5
Standard No.132		3.06	1000	306	1007

varies inversly with the water temprature .

In figure 6 the Sr concentrations for the 29 samples are plotted against their dolomite content . It can be seen that in general the Sr content varies directly with the dolomite content . This observation appears to be contrary to expectations according to our working hypothesis .

Assuming the Flagstaff dolomites are of secondary origin , one sees that the dolomite content is an expression of dolomitization. In as much as the Flagstaff dolomites show higher Sr concentrations

FIGURE 5. Strontium Concentration vs. Intensity in CPS.



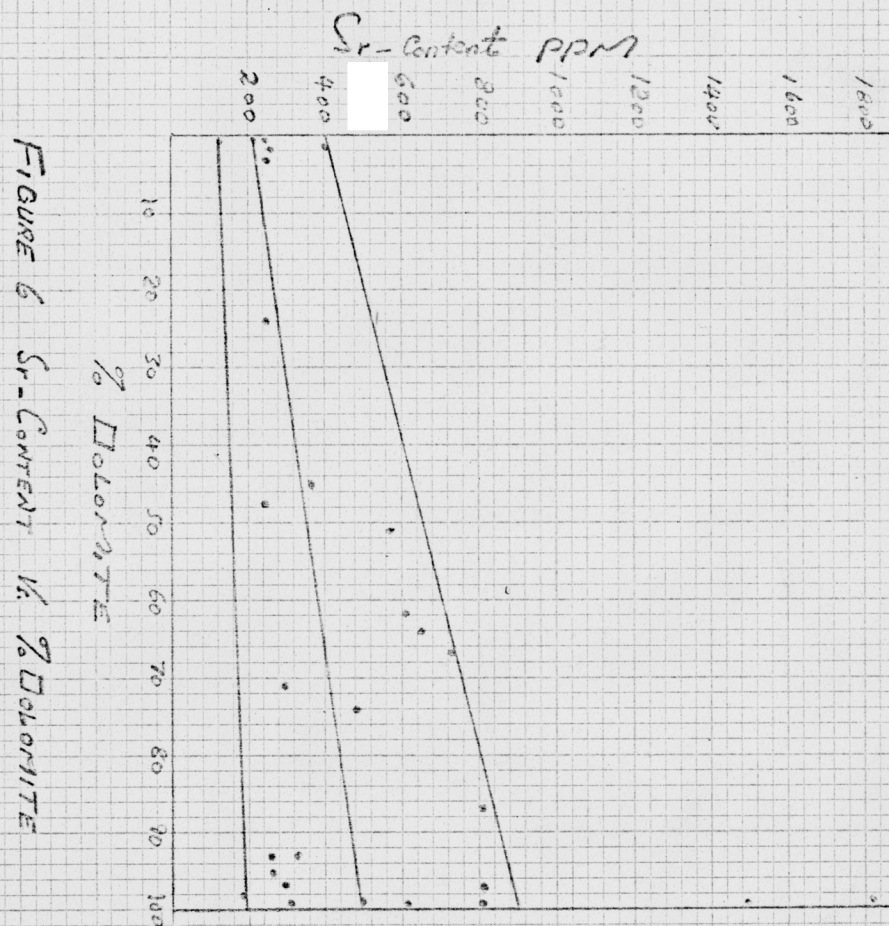


FIGURE 6 Sr-Content vs. % Dolomite

than the limestones, one concludes that dolomitization may increase the Sr concentration.

The exact nature of the replacing solutions that account for the introduction of Sr into the carbonate rocks is yet to be investigated and determined. In the preceding paragraph we have assumed that the same solutions that caused the dolomite content to increase also increased the Sr concentration. This assumption need not be the case. The Sr may have been introduced by solutions that differ in their chemical and biological aspects.

Chillinger et al.(1967b) made it clear that the strontium concentration in chemically formed carbonates are affected by "(1) contemporaneous coprecipitation of Sr and(2) subsequent introduction of Sr into the carbonates ". If the high strontium concentration is attributed to the introduction of Sr into the carbonate rocks by moving solutions and if these solutions happen to have a positive effect on the rate of dolomitization and assuming that the effect of other variables ,as yet to be determined, are such that they cancel each other , then one would expect the Sr concentration to increase with increasing % dolomite and decrease with increasing % calcite (table 2 and figure 6) .

Let one assumes that the prevailing chemical and biological variables are such that dolomitization increases at an increasing rate . It has been noted that Sr does not have to be introduced by

the same replacing solutions. Accordingly, such an adjustment may cause the subsequent introduction of Sr to decrease at an increasing rate. If so then one would expect the Sr concentration to decrease as the dolomite content increases .

The dolomites of the Flagstaff carbonates may be of primary origin. This means that the dolomites show higher strontium concentrations because of the corresponding higher rate of contemporaneous coprecipitation of their contained strontium. Hence dolomitization may not have either a positive or a negative effect on the strontium concentration.

One is therefore lead to the conclusion that dolomitization may affect the strontium content in either one of three ways :

(1) it may increase the Sr concentration, (2) it may decrease the Sr content or (3) dolomitization may have a neutral effect on the Sr concentration .

In as much as the Sr content of the Flagstaff dolomites is higher than that of the limestones one sees that in this case carbonate mineralogy is not a primary factor in determining the Sr concentration. Chilinger et al. (1967b) suggested that Sr does not have to be in the carbonate lattices. Graf (1960) pointed out that celestite may be present as an accessory mineral in carbonate sediments. Turekian et al (1952) found that crystal form of marine

carbonates to be a secondary factor in determining the Sr-content. Graf (1960) in discussing marine carbonates says that "dolomites apparently may contain either less or more Sr than limestones depending upon whether celestite is present " .

It has been observed earlier that the Flagstaff formation contains assemblages of fresh water fossils such as gastropod genera *Goniobasis*, *Gyraulus*, *Physa*, *Viviparus*, *Lioplacodes* and *Hydrobia* (LaRocque 1956) . The rocks also contain pelecypods and ostracods (Spieker et al .1925 ; Roy 1962) . Graf (1960) pointed out that according to Turekian and Armstrong the average Sr content of 49 recent clams and of 47 recent snails is 1570ppm and 1390 ppm respectively. Thus the Flagstaff fossils may have a direct effect on the strontium distribution. Untill the strontium content of these fossils is established no further comment on their exact role in determining the strontium concentration can be made here .

Conclusion :

The Flagstaff formation consists chiefly of fresh water limestone. It contains fresh water fossils such as gastropods pelecypods and ostracods . The Flagstaff limestone is Tertiary in age (upper Paleocene - lower Eocene) . Although an inverse relationship was expected to hold between the % dolomite and the strontium concentration , it has been found as a result of

this investigation that the strontium concentration increases with increasing % dolomite and decreases with increasing % calcite . Because the dolomite content is an expression of dolomitization, one concludes that dolomitization may increase the strontium concentration ; it may also decrease the strontium content or it may have no effect on the Sr concentration . Untill the strontium distribution among the Flagstaff fossils is determined , no comment on their exact role in controlling the strontium concentration can be made here .

Acknowledgments :

I am indebted to Dr. Gunter Faure for providing the five standards used in calibration. Dr. Faure gave advice also on X-ray analysis. Thanks are due to Dr. M.P. Weiss for his field assistance and for providing the calcite calibration curve .

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